Hunter, in a personal communication to GRUFFYD (1965b) suggested that under certain circumstances *Chaetogaster l. limnaei* could become parasitic since it ingests material derived from its snail host. The appearance of carmine, PAS and alcian blue positive material in the digestive tract of *C. l. limnaei* maintained in pond water and then transferred to *Physa acuta* suggests evidence for the existence of parasitism in the relationship between these organisms.

## ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of Dr. William J. Clench, Honorary Curator of Mollusks, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, for his identification of the physid snail used in this study.

## Literature Cited

GRUFFYDD, LL. D.
1965a. Evidence for the existence of a new subspecies of *Chaetogaster limnaei* (Oligochaeta) in Britain. Journ. Zool. 146: 175 - 196
1965b. The population biology of *Chaetogaster limnaei limnaei* and *Chaetogaster limnaei vaghini* (Oligochaeta). Journ. Anim. Ecol. 34: 667 - 690

HUMASON, GRETCHEN LYON
1967. Animal tissue techniques. 2nd ed. W. H. Freeman and Company, San Francisco, ix + 569 pp.; illus.

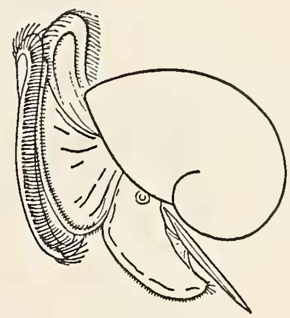
MICHELSON, EDWARD HARLAN
1964. The protective action of *Chaetogaster limnaei* on snails exposed to *Schistosoma mansoni*. Journ. Parasitol. 50: 441 - 444

SHIGINA, N. G.
1970. A contribution to the feeding of *Chaetogaster limnaei* (Oligochaeta : Naididae) and its role in the extermination of trematode larvae. Zol. Zhur. 49: 673 - 679

TRIPP, M. R.
1961. The fate of foreign materials experimentally introduced into the snail *Australorbis glabratus*. Journ. Parasitol. 47: 745 - 751

VAGHIN, V. L.
1946. On the biological species of *Chaetogaster limnaei* K. Baer. Compt. Rend. Acad. Sci. U. R. S. S. 51: 481 - 484

WAGIN, W. L.
1931. *Chaetogaster limnaei* K. Baer als Cercarienvertilger. Zool. Anz. 95: 55 - 59



# Relative Abundance of *Mercenaria mercenaria notata* in Estuaries in South Carolina

BY

PETER J. ELDRIDGE[2], WAYNE WALTZ[2], AND HOLLAND MILLS[3]

*Mercenaria mercenaria notata* (Say, 1822) occurs from the Gulf of St. Lawrence to Florida and the Gulf of Mexico (ABBOTT, 1974). However, there is little information concerning their relative abundance because this form is not separated by commercial clammers and few researchers have studied this aspect of their distribution. Personnel of the South Carolina Wildlife and Marine Resources Department for the past 2 years have been conducting a state-wide survey to estimate subtidal distribution and abundance of hard clams, *M. mercenaria* (GRACY, 1974). Clams collected in the survey have been sent to the Marine Resources Research Institute for identification and measurement.

Clams were collected by hydraulic patent tongs that were selective for clams that were equal to or greater than 25 mm in width. Therefore, measurements do not reflect true size distribution of the clam resource.

*Mercenaria mercenaria notata* were noted in collections of clams from 11 locations in South Carolina waters where they comprised 0.71 to 2.17% of the total number of clams sampled (Table 1). The best estimate of the relative abundance of *M. mercenaria notata* appears to be 1.23%, the figure obtained when all available data are

[1] Contribution No. 45 from the South Carolina Marine Resources Center. This study was conducted in cooperation with the United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service under Public Law 88-309, Project No. 2-179-D

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[3] Office of Conservation and Management, Division of Marine Resources, South Carolina Wildlife and Marine Resources Department

**Table 1**

Sampling data where specimens of *Mercenaria mercenaria notata* (Say 1822) were collected in estuaries of South Carolina

| Location | Latitude (approximate) | Longitude (approximate) | Date | Mean Depth (m) | Bottom Type | Total Clams Collected | Total Number M.m.n. | Percent M.m.n. | Total Shell Length (mm) |
|---|---|---|---|---|---|---|---|---|---|
| North Santee River | 33° 10′ N | 79° 15′ W | 28 I 74 | 2.8 | Sand-shell | 108 | 1 | 0.93 | 61.7 |
| | " | " | 05 III 74 | 2.8 | " | N.A. | 2 | – | 47.0, 61.5 |
| | " | " | 27 VIII 74 | 2.8 | " | 209 | 2 | 0.96 | 60.0, 64.6 |
| South Santee River | 33° 08′ N | 79° 16′ W | 12 VIII 74 | 2.4 | Sand-Shell | 300 | 3 | 1.00 | 37.1, 46.2, 63.6 |
| | " | " | 23 XI 74 | 2.4 | " | N.A. | 1 | – | 88.1 |
| Bull Bay | 32° 56′ N | 79° 35′ W | 26 III 74 | 0.1 | Sand-Shell | 111 | 1 | 0.90 | 54.3 |
| See Wee Bay | 32° 57′ N | 79° 39′ W | 15 III 74 | 3.4 | Mud-Sand | 142 | 3 | 2.11 | 65.4, 68.3, 69.4 |
| Alligator Creek | 33° 06′ N | 79° 21′ W | 30 IX 74 | 3.5 | Mud-Sand | 135 | 1 | 0.74 | 81.8 |
| Parris Island | 32° 17′ N | 80° 41′ W | 30 VII 74 | 4.3 | Sand-Shell | 53 | 1 | 1.89 | 30.4 |
| Fish Creek | 32° 29′ N | 80° 23′ W | 28 V 74 | 2.0 | N.A. | 140 | 1 | 0.71 | 53.2 |
| Clark Creek | 33° 00′ N | 79° 28′ W | 08 IV 75 | 3.5 | Sand-Shell | 74 | 1 | 1.35 | 86.5 |
| Key Creek | 33° 01′ N | 79° 25′ W | 08 IV 75 | 3.5 | Sand-Shell | 74 | 1 | 1.35 | 83.5 |
| Devils Den Creek | 33° 01′ N | 79° 23′ W | 22 IV 75 | 3.5 | Sand-Shell | 55 | 1 | 1.82 | 53.1 |
| Back Creek | 32° 54′ N | 79° 37′ W | 29 IV 75 | 2.3 | Sand-Shell | 138 | 3 | 2.17 | 67.0, 70.4, 76.1 |
| Total with known sample size | | | | | | 1539 | 19 | 1.23 | |

N.A.—Information not available

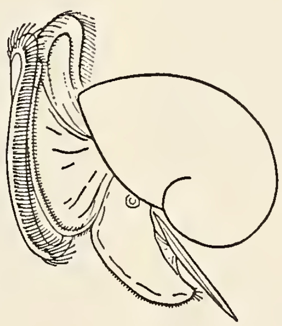
utilized. The estimate is for larger clams but probably holds for smaller clams as well.

## ACKNOWLEDGMENTS

The authors wish to thank Mr. Michael Baily, who assisted in the field work, and Ms. Mary Anne Barwick, who typed the manuscript.

## Literature Cited

Abbott, Robert Tucker
1974. American seashells Van Nostrand Reinhold Co., New York, 2nd ed.,; 663 pp.; 24 color plts.; numerous figs.
Gracy, Robert C.
1974. Management and development of the shellfish industry in South Carolina. Ann. Rprt. Project 2-179-D in coop. w. Natl. Mar. Fish. Serv., Dept. Commerce. Under Public Law 88-309: 22 pp.



# Effects of Substratum on Growth of the Bivalve *Rangia cuneata* Gray, 1831

BY

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(4 Text figures)

## INTRODUCTION

THE BRACKISH WATER bivalve *Rangia cuneata* Gray, 1831, a member of the family Mactridae, has been reported from Virginia estuaries in the past few years. This species, until recently common only along the Gulf Coast, occurred in estuaries from New Jersey to Mexico during the Pleistocene (RICHARDS, 1938), and now seems to be reoccupying its former range. Live *R. cuneata* on the east coast were first reported from North Carolina in 1955 (WELLS, 1961), Florida in 1961 (WOODBURN, 1962), Virginia in 1960 (WASS, 1972), the Potomac River in 1964 (PFITZENMEYER & DROBECK, 1964), upper Chesapeake Bay in 1966 (PFITZENMEYER, 1970), and the Elk River, Maryland, in 1968 (GALLAGHER & WELLS, 1969). The most common explanations of the range extension of *R. cuneata* have been reviewed by HOPKINS & ANDREWS (1970).

The literature on the growth of *Rangia cuneata* is meager. The larval development was studied by CHANLEY (1965) who reported termination of the straight-hinge stage at about 130 $\mu$m length. In a study of environmental effects on the reproductive cycle and larval development, CAIN (1973) reported the greatest growth of larvae at 27 - 32° C and 10 - 20‰ salinity.

Growth of adult *Rangia cuneata* was first studied by FAIRBANKS (1963), who correlated biological and physical factors in Lake Pontchartrain, Louisiana, with length, weight and population density. He attributed differences in abundance, size and growth to physical and chemical properties of the sediments. Growth, as indicated by annuli, was faster in sandy areas, with clams reaching 15 - 20 mm in length the first year and adding 5 - 10 mm the second and 4 - 5 mm the third year. *Rangia cuneata* were generally more numerous but smaller and slower growing in muddy areas.

WOLFE & PETTEWAY (1968) constructed a hypothetical von Bertalanffy growth curve based on data from clams collected over a two-year period at one station in North Carolina. They estimated that *Rangia cuneata* required 10 years to reach its asymptotic length of 75 mm in the area sampled. This is in general agreement with the estimates of FAIRBANKS (1963) and PFITZENMEYER & DROBECK (1964). No mention was made of the substratum or salinity regime from which these clams were collected.

TENORE, HORTON & DUKE (1968) found clay-silt sediments with high concentrations of phosphate or organic matter to be least favorable for growth, while sand with high nutrient levels was the most favorable. Uptake of radionuclide labeled detrital material indicated that *Rangia cuneata*, although morphologically a typical filter-feeder, can obtain organic matter and phosphate from the sediments, either by direct ingestion or by feeding on bacteria associated with these materials.

GODWIN'S (1968) distributional analysis of *Rangia cuneata* beds in the Altamaha River, Georgia, indicated no effect of salinity or substrate on size. However, he felt that salinity was the most important limiting factor governing the occurrence of *R. cuneata* and bottom type was a major factor controlling its distribution and density.

## METHODS AND MATERIALS

The experimental sites for this study were around Hog Island in the oligohaline section of the James River, Virginia. Sampling was conducted in 4 areas, labeled A, B, C, and D, each area having having one station (m) in a mud bottom about 3 m deep and one (s) in a sand bottom about 1 m deep (Figure 1). The sand stations were

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located on the submerged portions of beaches where the sandy bottoms probably resulted from wave turbulence rather than high current velocity. The sampling sites were chosen so that the areas differed mainly in salinity and stations within an area differed primarily in type of substratum.

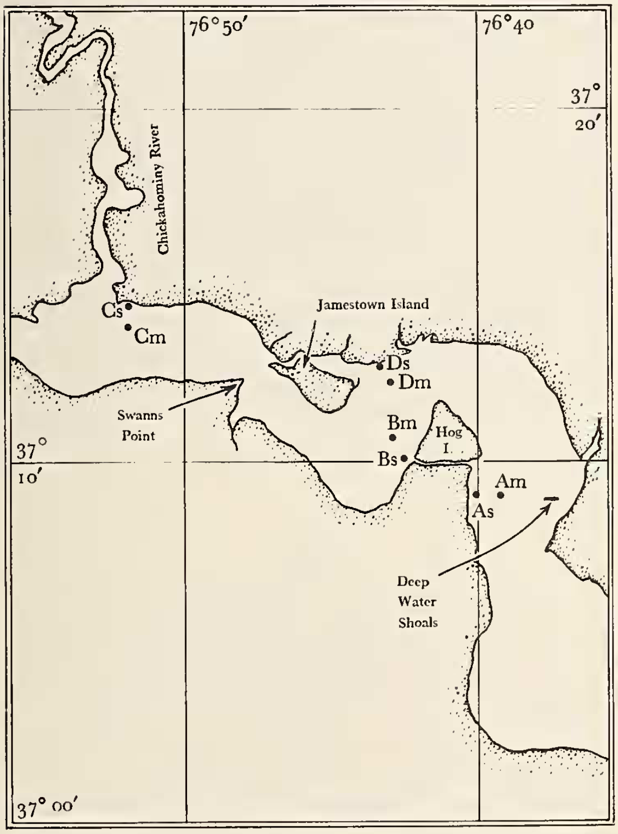


Figure 1

Location of Growth Stations in the James River Estuary, Virginia

Area A, about 25 nautical miles (46 km) above the river mouth, was located in what appeared to be the most seaward well established population of *Rangia cuneata*. Areas B and D were on opposite sides of the estuary at about river mile 32 (51 km). Area C, at mile 40 (64 km) near the mouth of the Chickahominy River, was in an upper estuarine population of *R. cuneata*. Although the clam is found another 40 km upstream, this region is typically tidal fresh water and was not considered in the present study.

Bottom water samples were taken bi-weekly at each station. For all samples temperature was measured immediately with a mercury thermometer while dissolved oxygen samples were fixed and returned to the laboratory for analysis by the Winkler method. Salinity was determined in the laboratory with an induction salinometer. At stations Ds and Dm current velocity, suspended solids concentration, salinity and dissolved oxygen data were collected every hour over a full tidal cycle on September 22, 1972, beginning just after low slack water. Current velocity 25 cm above the bottom was measured with an impeller-type meter, and water samples, integrating conditions between 5 cm and 16 cm above the bottom, were taken with a horizontal Van Dorn bottle. Suspended solids samples were stored on ice overnight, then a measured volume was vacuum filtered through a pre-weighed 0.80 $\mu$m filter pad, washed with distilled water and dried at 100° C for 24 hours. After cooling in a desiccator, they were weighed twice and the mean weights were converted to mg/*l*.

Particle size distribution in the top 5 cm of sediment at the 8 stations was determined from 2 samples, taken at the beginning and end of the study. All samples were treated with sodium hexametaphosphate to disperse aggregates. The sand fraction was separated by wet screening and the mud fraction was analyzed by the standard pipette technique. The results of the 2 sediment samplings, being very similar, were averaged and presented as the particle size distribution characterizing each station during the experiment.

Growth studies were begun in July, 1971. All experimental *Rangia cuneata* 30 mm to 40 mm long were collected by dredge at station Bm, while those 40 mm to 50 mm long and 50 mm to 60 mm long were collected by hand at Bs and Ds, respectively. Approximately 125 clams in each 10-mm length interval between 30 mm and 60 mm were returned to the laboratory where they were brushed clean, measured, weighed and numbered for planting.

Ten clams were selected randomly from a size class, towel dried, weighed to 0.1 g and length and width were measured to 0.1 mm. These clams were set aside and the procedure repeated until 100 clams had been selected from that size class. By this time the shells had evaporated to complete dryness and an identifying number was painted on each clam using Marktex Tech-Pen and Ink (Mark-Tex Corp., Englewood, New Jersey). Fifty clams of each size class were selected to be planted in sand and 50 in mud in each study area.

Planting beds had been previously prepared at all 8 stations using SCUBA gear, which was also employed in planting and recovering marked clams. At each station clams within a marked area about 1.5 meters square were removed. By the time the numbered clams were ready for planting, the currents had reworked the sediment in the planting beds until they were indistinguishable from the surrounding sediment. The clams were distributed evenly over the cleared area and pushed into the substrate in approximately the natural orientation. One hundred and fifty clams between 30 and 60 mm long were planted at each of the 8 stations. In addition, 50 clams 20 to 30 mm long were planted at both Ds and Dm on August 19, 1971, and on September 1, 1971, about 30 clams less than 20 mm long were planted at these stations.

Clams were recovered 1 year ± 2 days after planting, and were returned to the laboratory, dried, weighed and measured as before planting.

Although clams of the same sizes had been planted at all 8 stations, size-related biases may have occurred in the subsamples recovered at some stations. This was tested by an analysis of variance comparing the lengths at the time of planting of those clams which were recovered at each station.

The growth of the clams at the various stations was compared by constructing Walford plots for each station (Lindner, 1953; Walford, 1946; Wolfe & Petteway, 1968). This method plots length at time t (at planting) on the X axis and length at time t + 1 (at recovery 1 year later) on the Y axis. The result is a linear "transformation" of the data. An analysis of covariance was then performed to compare the least squares regression lines obtained from the data for each station. Contrasts among the adjusted means of the regression lines were made by Scheffe's method (Guenther, 1965) at the 0.05 level. No acceptable multiple contrast method was available for contrasting the slopes of the lines; therefore, visual inspection was employed to establish apparently homogeneous groupings of regression lines. Then covariance was used to test the identity of the lines within each group and to compare the pooled data for each group to lines outside the group. The author was aware that with such a multiple use of "F" the probability level decreases at an undetermined rate. However, the change is slight for a small number of comparisons and can be offset by the use of a lower alpha level.

## RESULTS

Water temperature ranged seasonally from about 4°C to 29°C, with daily and tidal temperature variations at a station as great as differences between stations on the same day. Dissolved oxygen was usually somewhat below saturation, ranging from 12 mg/$l$ in winter to about 6 mg/$l$ in autumn at all stations. All mud stations usually had slightly higher salinity and lower dissolved oxygen than the shallower sand stations. Salinity was highly variable seasonally with most areas showing measurable salinity in late summer, and even area A becoming fresh during periods of high runoff. Area A was the highest salinity area investigated, with a range of 0.2‰ to over 17.1‰ between August, 1970, and March, 1972. Salinities in area B ranged from 0.1 to 14.4‰ while those in area D were usually 0.1 to 0.5‰ higher. In contrast to the other areas, C does not experience salinity every year. In October, 1970, salinity reached 9.4‰ at Cm and after mid-November, 1970, did not exceed 1‰. The temperature, salinity and dissolved oxygen conditions at each station are presented in detail in Peddicord (1973).

The results of the sediment particle size analysis for all 8 stations are presented in Table 1. All sand stations had very similar particle size distributions, while the mud stations showed more variability. Station Dm had more sand than the other mud stations, but did not approach the sand content of the sand stations. All mud stations had approximately 80% or greater silt-clay content.

Table 1

Percentage composition by weight of the sediment at each of the 8 growth stations.
Values given are the mean of two determinations.

| Station | % fine clay <0.49μm | % coarse clay 0.49-3.9μm | % silt 3.9-62.5μm | % sand >62.5μm |
|---|---|---|---|---|
| As | 1.80 | 4.84 | 7.64 | 85.73 |
| Bs | 0.85 | 5.67 | 12.33 | 81.16 |
| Cs | 2.72 | 4.81 | 10.68 | 81.79 |
| Ds | 0.58 | 4.50 | 12.19 | 82.73 |
| Am | 18.67 | 17.19 | 57.67 | 6.47 |
| Bm | 23.86 | 26.23 | 47.64 | 2.27 |
| Cm | 29.71 | 33.02 | 30.22 | 7.06 |
| Dm | 16.62 | 18.33 | 42.28 | 21.77 |

Additional differences between the sand and mud stations were indicated by the study of suspended solids and current velocity in area D. The salinity at both stations varied about 1.5‰ over the tidal cycle and was generally lower at Ds than at Dm. Dissolved oxygen patterns were similar at both stations, but more variable at Ds. The